

Claims (as originally filed and published)

1. A method for producing a solid filament (1) from a liquid (2) in a vacuum chamber (70), with the steps:
 - liquefaction of a gas in a heat exchanger device (20) for producing the liquid (2), and
 - supplying of the liquid (2) via a supply line (27) and through a nozzle (30) into the vacuum chamber (70),**characterized in that**
 - the liquefaction of the gas in the heat exchanger device (20) comprises the adjusting of a p-T operating point of the liquid (2) at which the liquid (2) is converted into the solid aggregate state after exiting from the nozzle (30) into the vacuum chamber (70) and forms a collimated and stable jet.
2. The method according to Claim 1, in which the adjustment of the p-T operating point of the liquid (2) comprises a tempering of the liquid in the heat exchanger device (20) to an operating point temperature T_0 below which the liquid becomes solid.
3. The method according to Claim 1 or 2, in which the adjustment of the p-T operating point of the liquid (2) comprises a tempering of the liquid in the heat exchanger device (20) to an operating point temperature T_0 that is less than 1 degree above the triple point T_T of the liquid (2).
4. The method according to at least one of the preceding claims, in which the tempering of the liquid (2) takes place while it flows through the supply line (27).
5. The method according to Claim 4, in which the tempering of the liquid (2) takes place along the supply line (27) up to the nozzle (30).
6. The method according to at least one of the preceding claims, in which a temperature gradient is formed along the supply line (27) in the heat exchanger device (20) that is less than 2 degrees/cm.
7. The method according to at least one of the preceding claims, in which the tempering takes place in the heat exchanger device (20) with a liquid cooling medium.

8. The method according to Claim 7, in which the temperature of the cooling medium is adjusted with a thermostat (40).
9. The method according to Claim 7 or 8, in which a temperature or a vapor pressure of the cooling medium is measured in the heat exchanger device (20).
10. The method according to at least one of the preceding claims, in which an optical measuring of the liquid (2) exiting into the vacuum chamber (70) takes place.
11. The method according to Claim 9 or 10, in which at least one of the parameters gas pressure, supply volume of the cooling medium and temperature of the cooling medium in the heat exchanger device (20) is adjusted as a function of the result of the temperature measurement, the vapor pressure measurement or the optical measurement.
12. The method according to Claim 11, in which a control circuit is formed for adjusting the at least one parameter.
13. The method according to at least one of the preceding claims, in which the liquid (2) in the nozzle (30) is subjected to a jet formation.
14. The method according to at least one of the preceding claims, in which the supplied gas is a noble gas.
15. The method according to Claim 14, in which the supplied gas is xenon.
16. The method according to at least one of the preceding claims, in which the p-T operating point of the liquid (2) is selected in such a manner that the liquid (2) becomes solid after exiting from the nozzle (30) within a freezing length (a) that is less than 10 mm.
17. A nozzle arrangement (10) especially for producing solid filaments (1) in a vacuum, that comprises:
 - a heat exchanger device (20) for producing a liquid (2) from a gas, and
 - a supply line (27) with a nozzle (30) through which the liquid (2) can exit into the vacuum,**characterized in that**

- the heat exchanger device (20) is adapted for adjusting a p-T operating point of the liquid (2) such that the liquid (2) can be converted after exiting from the nozzle (30) into the vacuum into the solid aggregate state and a collimated and stable jet form.
18. The nozzle arrangement according to Claim 17, in which the heat exchanger device (20) extends along the supply line (27).
 19. The nozzle arrangement according to Claim 18, in which the heat exchanger device (20) extends along the supply line (27) up to the nozzle (30).
 20. The nozzle arrangement according to at least one of Claims 17 to 19, in which the heat exchanger device (20) extends over a length of at least 40 cm along the supply line.
 21. The nozzle arrangement according to at least one of Claims 17 to 20, in which the supply line (27) runs helically through the heat exchanger device (20).
 22. The nozzle arrangement according to at least one of Claims 17 to 21, in which the supply line (27) has a wall thickness in a range of 0.1 mm to 0.5 mm.
 23. The nozzle arrangement according to at least one of Claims 17 to 22, in which the heat exchanger device (20) is a counterflow cooler.
 24. The nozzle arrangement according to at least one of Claims 17 to 23, in which the heat exchanger device (20) contains a liquid cooling medium.
 25. The nozzle arrangement according to at least one of Claims 17 to 24, in which the heat exchanger device (20) comprises a tubular cooling jacket (21) on whose end (22) the nozzle (30) is arranged.
 26. The nozzle arrangement according to Claim 25, in which the nozzle (30) is demountably arranged on the cooling jacket (21).
 27. The nozzle arrangement according to Claim 25 or 26, in which the nozzle (30) is adjustably arranged on the cooling jacket (21) in such a manner that the orientation of a dispensing direction of the nozzle (30) can be changed relative to a longitudinal extension of the cooling jacket (21).

28. The nozzle arrangement according to at least one of Claims 17 to 27, in which a screening device (35) is provided that serves for thermal insulation of the nozzle (30).
29. The nozzle arrangement according to at least one of Claims 25 to 28, in which a fastening device (50) is provided for fastening the cooling jacket (21) to a vacuum flange.
30. The nozzle arrangement according to at least one of Claims 25 to 29, in which the heat exchanger device (20) is connected to a thermostat (40) with which the cooling medium in the heat exchanger device (20) can be tempered.
31. The nozzle arrangement according to Claim 30, in which the thermostat (40) is arranged in such a manner that it is decoupled from oscillations relative to the heat exchanger device (20).
32. The nozzle arrangement according to Claim 30 or 31, in which the heat exchanger device (20) is connected via thermally insulated lines (24, 25) to the thermostat.
33. The nozzle arrangement according to at least one of Claims 17 to 32, in which a temperature sensor or vapor-pressure sensor is arranged in the heat exchanger device (20).
34. The nozzle arrangement according to at least one of Claims 17 to 33, in which the supply line (27) opens at the nozzle (30) with a given convex inside contour (32) into an exit opening.
35. The nozzle arrangement according to at least one of Claims 17 to 34, in which the nozzle (30) is detachably connected to the supply line (27), a seal being arranged between the nozzle (30) and the supply line (27) which seal consists of an alloy of copper and beryllium.
36. An apparatus with a vacuum chamber (70) and a nozzle arrangement (10) according to at least one of the preceding claims for producing a solid filament from a liquid in the vacuum chamber (70).

37. The use of a method or of a nozzle arrangement according to at least one of the preceding claims for producing a frozen filament with a length of at least 10 cm and a diameter in a range of 10 μm to 100 μm .